

## Chapter 7

# Natural Gas Abundance

*Even a little certainty is a very dangerous thing.*

—SIR HERMANN BONDI, MASTER, CHURCHILL  
COLLEGE, 1983–1990

**T**he mind-set of *oil and gas* has hidden the importance and understanding of natural gas within the perception of oil and the understanding of liquids. My college degree is in petroleum geology, and today most students continue to study petroleum geology and petroleum engineering. Petroleum is defined in Webster’s dictionary as “an oily flammable bituminous liquid,” and it has been my lifelong experience in the “oil and gas” industry that the mind-set of this industry that searches for and produces an oily, flammable, bituminous liquid is difficult to change. One of the early oil industry’s most successful and highly regarded geologists, Wallace Pratt, once famously said, “Where oil fields are really found . . . is in the minds of men . . .”<sup>1</sup>

This statement has been widely quoted and accepted by explorationists as a mantra, so if one's mind-set developed beginning with education in the technical fields of petroleum and continued through the daily vernacular of the industry with such statements as "I am an oil field hand," or "We are headed out to the oil patch," when in fact, they are going out to a natural gas field to work on natgas wells, it becomes easier to understand how the mind-set bias is toward oil and how oil accumulates and is trapped. We must never underestimate the lasting and controlling power of words.

It has been this oil mind-set that has led to an underappreciation of natgas abundance even within the oil and gas industry itself. Unfortunately, it will be a while before the thinking of the largest international oil companies (IOCs) really begins to change, although the process has indeed begun. It is very difficult to break out of the blinders that are generally created by what we learned during our college educations, particularly in the scientific disciplines. Because a majority of senior staff and management of the IOCs are over 50—most approaching retirement—they are deeply steeped in the ways and thinking of oil. After all, this has been the basis of an oil-focused education and of decades of enormous successes.

A true story illustrates the point. In October 2007, I spoke at London's globally renowned "Oil and Money" Conference. I delivered a speech about my belief that the world's energy future is what I call "The Age of Energy Gases," Chapter 13 of this book. Included were the topics of natural gas abundance and the many characteristic differences between natgas and oil, as described in Chapter 6. After the speech, a young man who appeared to be in his mid-40s came up to me and introduced himself as a graduate of the University of Oklahoma with a degree in petroleum engineering. He was employed by one of Houston's most successful energy investment banking firms. He went on to tell me, "I feel a little embarrassed about this, but I must admit that I have never thought about all those differences between oil and natural gas."

After decades in the industry, I know this is no isolated incident, but rather that his way of thinking is the mainstream. No one can really understand and grasp the significance of natural gas and its capacity as a major solution to our energy and climate problems

until these differences are thought about. As a broad generality, the senior technical staff and management of the IOCs, the state-owned oil companies (SOCs), as well as many of the smaller exploration and production companies of the world operate within the same controlling mind-set as that young man from Houston. It is no surprise that the general public and most politicians also lack a depth of natural gas understanding. Even in 2008, Red Cavaney, then president and CEO of the American Petroleum Institute, was being interviewed by CNBC's Maria Bartiromo. She asked, "The most viable alternative to oil when it comes to transportation—what is it?" Cavaney instantly responded, "There really isn't a viable alternative . . ." <sup>2</sup> Thus, natural gas, which already runs more than eight million vehicles in the world, wasn't even a possibility in his mind.

The United States during the past few years has been the best example of how this oil mind-set has determined the successful players in the ongoing development of new so-called "unconventional" natural gas supplies. The IOCs and other oil companies—with their legacy U.S. natural gas production (most of which was found decades ago in their search for oil)—all have declining natural gas production today. For decades, they have viewed the United States as a mature, highly developed oil and gas province with little remaining potential. The accurate oil forecast that has now become quite famous, made by Shell Oil's renowned geologist M. King Hubbert—that oil *and* gas production would peak in the United States in the 1970s<sup>3</sup>—became reality. The potential for large fields of oil and gas was largely eliminated from the minds of exploration geologists in the oil companies that were charged with finding new and ever-growing giant oil accumulations. This oil and gas mind-set translated into the mistaken thinking that if there is little potential for oil in the United States, there is also little potential for natural gas. Although natgas may be on the verge of breaking out of this—even within the oil companies—it is still difficult because senior management and technical staff will continue to struggle to think beyond the limits of oil.

It is no surprise that the most successful natgas producer in the United States, Chesapeake Energy—which has recently surpassed all the oil companies to become the number one producer of American natural gas—is led by a former *history* major from Duke University with

no technical petroleum education. Aubrey McClendon, Chesapeake's chairman and CEO, co-founded the company only 20 years ago. Then, it was just another tiny Oklahoma-based independent energy company in the midst of America's oil-mature, natural-gas-abundant Mid-Continent region. But Aubrey the historian had a sense that natgas, as he often likes to say, is "on the right side of history." He believes in natural gas abundance, and he has a lot of entrepreneurial determination, drive, and luck. Moreover, he has no real competition from older, well-established, and financially more capable oil companies, such as ExxonMobil, BP, Chevron, and Conoco Phillips, all with enormous legacy assets in the United States. With all this going for him, he was able to surpass all the oil companies in spite of their hundred-year history and legacy oil and gas production in America.

There is no question that this outstanding accomplishment by Chesapeake belongs in the list of good examples of the "could only happen in America" success stories, but it is an equally important story of the profound value of going beyond the mental limits placed on us all by decades of conventional wisdom. Without the technical bias of petroleum, Aubrey easily grasped the understanding that natural gas supplies in the United States were abundant and not connected to the mature stage of development and limits of oil. As Aubrey said to me during a discussion about geology, "the shales are something I can understand," and it certainly did not hurt that he knew the history of natural gas production in the United States—that natgas was first produced near Fredonia, New York, from a reservoir that was not conventional in oil parlance, but rather from unconventional shale. During the last decade, as prices rose and natural gas became profitable to produce, Chesapeake and other like-minded independent gas-not-oil producers began to drill in these areas.

As a matter of fact, during this same period of phenomenal growth by the natgas-oriented group of American independent contenders, many of the oil companies—because of their own perception of limited opportunities within the oil and gas industry—were liquidating themselves through large stock buybacks and increased dividends. Today, the oil companies will not be participants unless they catch up by buying out natural gas independents, just as Conoco Phillips did when it acquired Burlington Resources in 2006, an offshoot of El Paso

Natural Gas Company with excellent American natgas reserves and potential. Jim Mulva, the CEO of Conoco Phillips, seems well ahead of his peers. Upon the acquisition of Burlington Resources, he said, “We’ll be a major player with respect to gas in North America for decades to come.”<sup>4</sup> Natgas is truly the one alternative to both coal and oil that can be scaled up around the world to solve our looming energy and climate challenges. Of course, to have the capacity to scale up to the quantities of production necessary to become an effective alternative to coal and oil requires natural gas *abundance*.

### **Mother Nature: Cookin’ with Gas**

As noted, natural gas is physically and chemically different from oil. We know that natural gas has both biological and nonbiological origins, can be created biologically within hours in our stomachs and refuse dumps, and was also part of the primordial molecular cloud at the creation of the universe. In our solar system, recent decades of space exploration have shown conclusively that natgas is abundant throughout our solar system. This gas is thought to be nonbiological. Natgas has now been detected on so many planets in significant quantities that NASA is studying the possibility of using natural gas for interplanetary travel.<sup>5</sup> The only possibility for biological origin of these vast quantities of natural gas in our solar system would be natgas generated by microbes below the surface of all of these planetary bodies. This would also mean that there is abundant, primitive life throughout our solar system and probably much of the universe, ratifying the Pan-Spermia or Pan-Galactic theory of life put forth by Cambridge’s renowned cosmologist Fred Hoyle. Indeed, if this was reality, then because we know that the same process of microbe-generated natural gas takes place below the Earth’s surface, it would be realistic to assume this microbial biological process may account for the creation of larger quantities of natgas on Earth than previously thought to be the case. “Unconventional” indeed.

The conventional wisdom that flows from the thinking surrounding the idea of oil and gas is that virtually all the commercial quantities of natgas on Earth come from the exact same geologically limited origin of oil that requires source rocks containing large quantities of

microbiological material that are subsequently buried to exactly the right depth necessary to create the conditions of pressure and temperature over a sufficiently long geologic period—at least hundreds of thousands if not millions of years—to *create liquid oil*. This has often been called by oil geologists the *kitchen* that is required to *cook* the oil, or the *physical window* for the conditions of oil's origin.

Natural gas is, of course, *also* created in large amounts right along with oil's process of origin. However, the natgas kitchen is vastly larger. That kitchen begins with the nearly ambient pressures and temperatures on Earth's surface, such as our stomachs and refuse dumps—right through and beyond the oil window—to the extreme and widely variable conditions of our solar system to the even-larger extreme of 900 degrees Celsius detected in the atmosphere of a planet in the constellation Vulpecula about 63 light years from Earth.<sup>6</sup> On Earth, natural gas exists and most likely also originates from the extreme conditions of great depths and extremely high pressures and temperatures where diamonds are formed of the purest carbon. We know natgas is present during the creation of diamonds because diamonds often have natural gas inclusions within them.

To further affirm the presence of natural gas deep within our Earth at levels where oil is almost nonexistent, natural gas has been found in the deepest wells ever drilled, including two test wells that were drilled entirely in granite rocks where most oil geologists don't believe oil and gas exist. Two of the granite test wells were drilled within the Siljan meteorite crater of Sweden. I was a consultant on that project because of my company's extensive deep natural gas drilling experience. The two wells were drilled to about 22,000 feet and 21,300 feet (6.7 and 6.5 kilometers, respectively), and I can personally attest to the fact that the natural gas measuring devices confirmed the presence of natural gas all the way to total depth. Although the two wells were never adequately tested for production potential, it is doubtful that commercial quantities of natural gas were found. Still, the fact that natural gas was present within granite rocks at great depths that have no biological accumulations or source rocks that the oil industry believes are *required* for the creation of oil and gas, and the fact that natural gas shows seemed to increase with depth, are certainly good indications of the wide occurrence of natural gas and its possible nonbiological origin on Earth.

## Deepest Wells in the World

In 1972, our company and Lone Star Natural Gas began drilling the deepest vertical well in the Western World to a depth of 31,441 feet in western Oklahoma. At that depth, the well encountered a strong, positive flow off bottom that began to lift the drill string, which weighed about a million pounds. The well's driller correctly lifted the drill pipe up in the derrick and closed the blowout preventers. The surface pressure gauge instantly indicated over 4,000 psi and built up to over 8,000 psi in about 10 minutes. The indicated pressure was over 31,000 psi at the well's total depth. This indicated the highest pressure ever encountered in the Earth at the time and probably remains a world record today. I won't go into all the exciting details of trying to deal with these never-before-encountered pressures, but suffice it to say that the technology of the time was not up to handling these conditions, and after about a day of watching the well circulate up natural gas and about a pickup-truck load of pure sulphur, we capped and cemented the well.

To this day, we have no understanding as to whether commercial quantities of natural gas were actually encountered, but we do know that significant amounts of natural gas exist at the total depth of the wellbore. While we were drilling the well, we entertained a group of Soviet scientists at the rig, a tour organized by the U.S. State Department. A few months later, when I delivered a paper about our experience drilling that well and other deep, high-pressure wells to the World Gas Conference in Nice, France, a group of Soviet scientists filled the entire first two rows of the auditorium and furiously took notes during my entire presentation. We would learn many years later that the reason for their great attention and the visit to the wellsite was that the Soviets were drilling the world's deepest test well in the Kola Peninsula. After more than a decade of drilling through solid granite rocks, this well reached 40,233 feet.<sup>7</sup> Much later, when scientific reports of the well reached the West, we learned that just as in the Sweden's Siljan crater, shows of natural gas were encountered throughout most of the borehole down to total depth. The logic that flows from the fact that natural gas is present in deep boreholes in granite rocks that do not contain the biological debris found in sedimentary rocks necessary for biological origin—combined with the presence of so much natural

gas on most of our solar system's planets—led to reasonable beliefs that natural gas is continually flowing from the Earth's interior mantle, just as it must be on planets throughout our solar system.

## Ubiquitous Natural Gas

So because natural gas exists in the universe at extremely high temperatures—throughout our solar system at extremes of both hot and cold—and is found deep within Earth at the depths, pressures, and temperatures where diamonds are formed, is encountered in measurable quantities in most of the world's boreholes, and found in the stomachs of animals and refuse dumps, I believe it is reasonable to believe its existence must be nearly pervasive in all the Earth's rocks.

Because of the pervasive nature of natural gas, the chance for commercial accumulations to be found are much better than those for oil, a liquid, viscous substance that cannot move through rocks easily and is encountered far less frequently within the world's boreholes. Oil's physical and chemical characteristics have created a comparatively limited window of existence compared to that of natural gas. These facts are a good indication that not only does more natural gas exist on Earth than oil, but also, unlike coal and oil, large quantities of natural gas may actually be renewable.

Additionally, natural gas can always be found in quantities varying from commercial production to only traces in coal deposits that are thought to have a somewhat similar origin as oil, but in contrast to the microbiology of oil's origin, coal is formed from macrobiology of the Earth's flora. It is logical to assume that significant quantities of natgas were also formed during the geological process of coal's origin. There is also lots of natural gas found with the world's peat bogs, but peat is created on or near the Earth's surface, and in a relatively short time period of thousands of years rather than over the geological eons of time required for the creation of coal and oil.

To sum up, we know much about natgas that does not apply to oil:

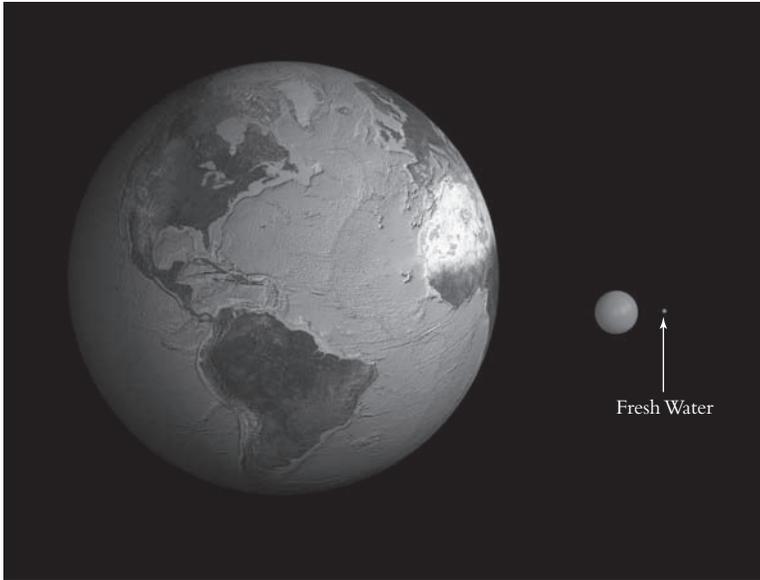
- Natural gas exists in the widest range of physical conditions of pressure and temperature.

- Natural gas was an abundant substance in the primordial molecular cloud following the Big Bang.
- Natural gas is created continuously by microbes within the Earth—we just don't know in what quantities.
- Natural gas was either around in large quantities from nonbiological creation beginning at the origin of the solar system or it is being created continuously at rates sufficient to create vast accumulations of natgas on planetary bodies throughout our solar system. Possibly, both are occurring.

Therefore, we can conclude that, in addition to the natural gas that was created during the creation of oil, and the natural gas that was also created in the same biological manner outside the physical conditions of the oil window, it is highly likely that Earth may also be blessed with an abundance of either nonbiologically created natural gas that has existed from the origin of our solar system, or that the Earth's natgas-producing microbes are creating natural gas in larger quantities than previously thought. The fact that all this natgas is *in addition* to the natural gas created along with coal and oil, coupled with the fact that natgas can be commercially produced from so many times the volumes of Earth's rocks than can oil, leads me to the conclusion that natgas should be considered the world's most abundant hydrocarbon. This conclusion is given further credence by the fact that gases are by far the most abundant state of matter in the universe, followed by the much smaller quantities of solids. Liquids are a transitional state of matter and only exist in relatively very small quantities on Earth, within our solar system, and across the universe. The evidence on Earth tends to confirm this same pattern of relative quantities. Exhibit 7.1, from Dave Gallo at Woods Hole Oceanographic Institution, shows Earth with all the water removed. The small sphere on the right represents all the oceans' waters and to its right, the tiny sphere, all the fresh water.

Another strong confirmation of the magnitude of natural gas abundance on Earth is provided by the ocean's vast natgas hydrate accumulations, estimated to hold at least several times more energy than all the world's coal and oil put together.<sup>8</sup>

So because the wide conditions of origin and places of existence, accumulation, and production of natural gas extend far beyond the



**Exhibit 7.1** Water Planet? We frequently hear that more than 70 percent of the world is covered by water. But how much is there really? On the left is an image of the Earth with all water removed. On the right is a sphere representing all the water on Earth (oceans, icecaps, glaciers, lakes, rivers, groundwater, etc.). To the far right (tiny sphere) is the FRESH water that is readily available to humanity to sustain life. Courtesy of Dave Gallo, Woods Hole Oceanographic Institution.

relatively narrow limits of coal and oil, we can better understand that natgas must be considered the most abundant hydrocarbon unless we can establish hard evidence to the contrary. Certainly, all the accumulated evidence over recent decades from natgas exploration and production, space exploration, and deep ocean exploration tends to confirm natgas abundance. This is why I believe natural gas resources are not only far larger than oil and most likely larger than coal, but possibly larger than both together.

## No Peak Natural Gas

The next important point in understanding natural gas abundance is the fact that natgas is not connected to peak oil. This is because of

its geologic difference from oil. Natural gas is always produced along with oil within limited and specifically defined geological containers we call structures or traps. But it also accumulates and can be commercially produced from so-called unconventional reservoir rocks, coal seams, shales, and tight sands not favorable for oil accumulations that may underlie an entire geologic basin. This means that the Earth's areas and volumes of rocks favorable for commercial natural gas production far exceed the volume of rocks favorable for the conditions of oil and gas accumulation. In fact, the Earth's volumes of unconventional reservoir rocks capable of commercial natgas production are many times, if not an order of magnitude, greater than the volumes of rocks capable of commercial oil production. Natural gas always exists and is produced along with oil, often equaling 20 percent to 40 percent of the total accumulation within an oil field. So because natural gas can be produced from so many times the volumes of rocks as can oil, it is easy to understand why the world's supplies of commercially accessible natgas are many times larger than those of oil. The only relationship natural gas has to peak oil is the natural gas that is produced along with oil from oil and gas fields from conventional reservoirs. It is only this oil-associated natgas production that will peak and decline along with oil production.

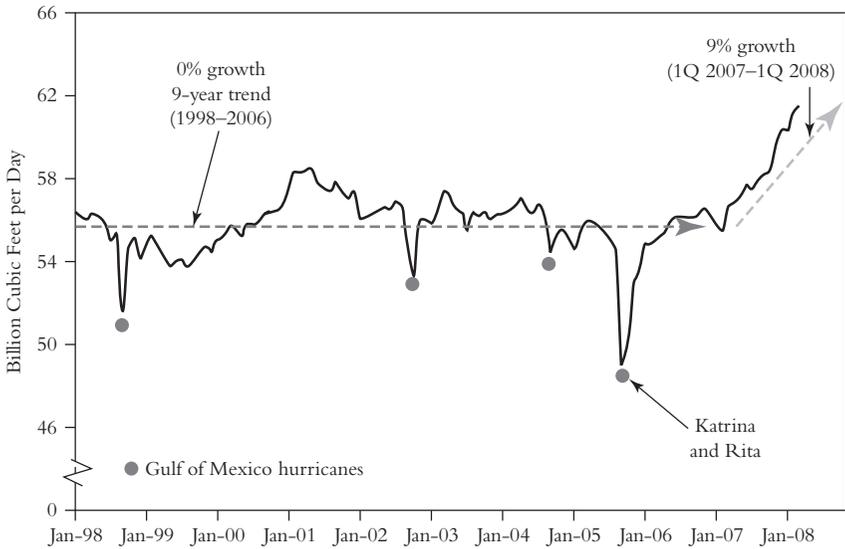
Because natural gas is also produced from unconventional reservoirs that likely hold much more natgas than conventional reservoirs, *peak oil* does not mean *peak natural gas*. This same mistaken fear of natgas shortages in the United States in the 1970s, coinciding with the beginning of peak oil in the United States, translated into many bad policy decisions, particularly, as we have seen, banning of natural gas's use in power generation and new industrial facilities. That one policy act has macroeconomically distorted the quantities of use of coal, oil, and natural gas in the United States until this very day. The large quantities of coal and oil consumption in the United States today—and their highly negative pollution, climate, economic, and security impacts on American society—are continuing remnants of these misguided policies, the result of failing to understand that peak oil does not mean peak natural gas and missing the fact that U.S. domestic natural gas was then, and is now, abundant.

## Unconventional Is Conventional

We must not make such mistakes again. The success of what the oil industry has called unconventional natural gas development proves that, although these rocks were called unconventional given the mind-set of the oil industry, they are likely to become the largest natgas-producing rocks for the world and should henceforth be considered *conventional* for natural gas production. I mention this because of the power of words and the concepts they convey. The fact is that the word *unconventional* conveys a large measure of limits and uncertainty that will tend to inhibit the world's policy makers from relying on natural gas.

Policy makers need the comfort of certainty to create policy that will impact populations for decades. So let me appeal to the world's policy makers. Today, we have more certainty about the abundance of natural gas supplies than oil. From the beginning of the natural gas industry in Fredonia, New York, natural gas has been produced from shales, so this really is not new. It is time to abandon the oil industry's concept that shales are unconventional and add them to the long list of *conventional* natural gas reservoirs.

The reality of this conventional-versus-unconventional paradigm shift in America's energy evolution can now be seen in the official U.S. statistics. The Energy Information Administration, in its *Energy in Brief* (June 2008), announced that "Natural gas production in the lower 48 states has seen a large upward shift." Further, the brief stated, "Recent growth in natural gas production in the lower 48 states breaks with historical trends." Exhibit 7.2 shows the dramatic change that is largely the result of new production in unconventional reservoirs. These official announcements were all *before* Chesapeake Energy announced that it had entered into a joint venture in the Haynesville Shale in northwest Louisiana and east Texas that it said will likely become America's largest natural gas field. The company announced the Haynesville Shale may contain 250 Tcf of recoverable natural gas, which would make it about the fourth largest in the world.<sup>9</sup> If natgas prices within most of the world's countries were uncapped, the global natural gas production chart could soon look exactly the same.



**Exhibit 7.2** Recent Growth in Natural Gas Production in the Lower 48 States Breaks with Historical Trends

Source: Energy Information Administration, *Energy in Brief* (June 11, 2008).

## More Natural Gas than the Market Can Use

As I write in early 2009, natural gas producers have been so successful in their efforts that once again there is a natural gas supply bubble—more natural gas than the market can possibly use. Cash prices last fall in the Rocky Mountains and Mid-Continent United States collapsed below \$2 per Mcf, or about \$12 per barrel of oil equivalent, even with significant Gulf of Mexico production still shut in from Hurricane Ike.

Because the price is dropping below the cost of finding, and gas flows are more than the market wants, American natural gas producers are once again cutting drilling budgets by billions for the coming years. Drilling rigs are being laid down, and once again we are going through another boom and bust. Although we are importing nearly \$500 billion in foreign oil each year and sending those payments to

foreign producers, the United States is awash in natural gas, which is clean, secure, and creates domestic jobs, but which is not being used for the benefit of the U.S. economy. It is a travesty, particularly during this time of great economic weakness, that we have policies that foster the continuing use of oil and keep domestic natural gas in the ground to the detriment of economic growth. By early spring 2009, as the price of natural gas crashed to below replacement cost, tens of billions of dollars of capital expenditures for future natural gas development had been canceled, revenue to U.S. farmers and landowners plummeted by tens of billions of dollars, and tens of thousands of jobs in the U.S. natural gas industry were lost.

### **In the Search for Oil We Find More Natural Gas**

Another good indication that natgas is far more abundant than oil is the fact that in the global search for oil and gas, a search that is principally funded by the big international and state-owned oil companies and focused on finding new oil reserves to replace declining oil production, more natural gas is being found than oil.

The AAPG, the world's most prestigious association of petroleum geologists, keeps records on the giant oil and gas fields found in the world each decade. During the last decade available, 1990 to 1999, 37 giant oil fields were found that contained 36,800 million "barrels of oil equivalent" (BOE). (The fact that the oil and gas industry normally keeps its statistics in BOE is another reminder of the oil mind-set and bias.) However, during the same decade, 40 giant natgas fields were found that contained 119,387 million BOE.<sup>10</sup> So, in a search directed largely by oil geologists seeking new oil supplies, *three times as much natgas was found than oil!* Digging a bit deeper, we find that about 30 percent of the BOE in the oil fields was actually natural gas. So in that decade, in spite of the fact that petroleum geologists and capital budgets were largely directed toward replacing oil supplies, *three to five times more natural gas was found than oil.*

Nigeria is a recent example of vast quantities of natural gas found in the search for oil. Nigerians have a saying that the country is a drop of oil in a bucket of natural gas.

Today, even with the continuing mind-set and bias of oil, natgas is revealed to be an abundant resource of primary energy worldwide in the estimates made by the world's experts. One of the most respected keepers of global energy statistics is the oil giant BP, formerly British Petroleum, whose former CEO, Lord John Browne, presciently launched a marketing campaign based on the letters BP, standing for "Beyond Petroleum." In 2007, BP estimated that the world's proven<sup>11</sup> natural gas reserves stood at 6,405 Tcf compared with 6,778 Tcf equivalent for oil and 23,727 Tcf equivalent for coal.<sup>12</sup> That would equal about a 64-year supply of proven natural gas at the world's present rate of consumption of about 100 Tcf per year.

### **More Proven Natural Gas than Is Estimated**

There is a very important point that must be made about proven natural gas reserves as compared with *estimates* of proven oil reserves that are generally in the ballpark or even sometimes overestimated, as we learned from Shell Oil's rather famous writedown of oil reserves. In 50 years of experience, the estimates I have received for the proven reserves of our company's natural gas wells and other natgas wells that I have studied in the early years of production equal only about 25 percent to 50 percent of the ultimate amount of natural gas that will actually be produced from those wells. It is only after about a decade of natural gas production, when well over half of the ultimate quantity of natgas has already been produced, that petroleum engineers begin to estimate ultimate proven reserves of natural gas wells near reality. Even then, estimates often only equal 70 percent to 80 percent of what wells will actually produce. These statistics do not apply to oil wells, but I won't go further into natgas reservoir engineering here. For those interested, check out my article "New Thinking about Natural Gas."<sup>13</sup> Before leaving this issue of underestimated natgas supplies, which I am quite certain is captured within all the natural gas statistics we see, let me make it clear that most of my natgas reserve understanding and experience comes from the onshore Mid-Continent region of the United States.

No doubt, my thinking is biased toward onshore natural gas production and its geologically older rocks that are generally not

found offshore in the oceans, where most reservoir rocks tend to be conventional, younger, and conform better to the understanding of petroleum engineering. Offshore reservoirs are usually classic sandstone reservoirs of high porosity and permeability, and therefore produce at very high rates and decline rapidly, so that the life of offshore wells is relatively short compared to onshore natural gas wells, with production lives that most always extend many decades longer. Therefore, reserve estimates for offshore natural gas wells are generally much more accurate. However, these younger offshore conventional reservoirs are also subject to the conventional natural gas bias of underestimation of ultimate recovery.

A good example of such underestimation that proves how mistaken these estimates of natural gas recoveries actually are is the 1977 study requested by the Secretary of the Interior, *The Potential for Increasing Production of Natural Gas from Existing Fields in the Near Term*. The study was conducted by the National Research Council (NRC) on six large offshore natural gas fields thought to be a good representation of all offshore Gulf fields. Three of the fields had been producing almost 20 years, two for about 10 years, and one for only 4 years when the report was published. Since the study, five of the six fields combined have produced 3.2 times the original 1977 estimate of remaining reserves.<sup>14</sup> One produced *only* 1.5 times the NRC's estimate; taken together, all six fields have produced 2.3 times the NRC estimate of remaining reserves. So as a general rule for natural gas reserve estimates, we are safe to assume that most proven natgas estimates of the ultimate quantities to be produced are significantly understated and often *dangerously* understated from the point of view of good policy decisions. Personally, I attribute these sustained underestimations to the physical difference between oil and natural gas that petroleum engineers have yet to grasp, and that is natural gas's ability to flow through rocks at rates so much faster and farther than oil. As pressures decline at the wellbore, natural gas will be drained commercially from much larger volumes of rocks than will oil. However, I am open to other ideas and would like to hear from those in the professions.

In short, the world's estimates of proven natgas reserves—that is, reserves that petroleum engineers give at least a 90 percent certainty of being present—are significantly underestimated. Even BP's proven

natural gas estimate for the world of 6,405 Tcf is in all likelihood no more than 50 to 60 percent of what will become the ultimate amount of natgas produced. BP's proven natural gas reserves are more likely to represent at least 80 years of consumption for the world at current rates. Not so bad when we recognize the yet-to-be-drilled natural gas reserves in the world will no doubt equal many times today's proven reserves. There is plenty of natural gas to step up natgas use globally in sufficient quantities to reduce the use of coal and oil and, by doing so, begin to clean up the planet, lower CO<sub>2</sub> emissions, and generally lower national security risks.

For the United States, I have even more confidence that the current EIA estimate of 238 Tcf of proven natgas reserves<sup>15</sup> will actually be about 50 percent of what is ultimately produced from those properties. I hold this view for three reasons:

1. My own historical experience with reserve estimates.
2. The NRC estimates for the six offshore fields turned out to be less than 50 percent of their ultimate production.
3. Nearly 50 percent of all producing wells in the United States are less than five years old, and the reality is that wells in their early years are significantly underestimated, often by at least 50 percent or much more.

So my bottom line is that U.S. proven reserves are much more likely to be over 400 Tcf than the 238 Tcf reported and generally accepted.

A major benefit for the future of natural gas as an energy solution to displace coal and oil is that it is a relative newcomer to the market. Comparatively little natural gas has yet been used or flared away. Unlike coal, mined and used in vast quantities for over 200 years with most of the "easy" coal long gone, and which has likely peaked in many of the world's mining areas, and unlike oil, produced in large quantities for over 100 years and which has also peaked in the majority of the producing regions of the world (and is in the process of peaking globally today), natgas has yet to hit its stride. Compared to the vast volumes of natural gas left for development in the world, only a small fraction has been found or used. With the exception of the United States, where the development of formerly unconventional, but now conventional,

shale natural gas resources has only recently begun, the rest of the world is virgin territory for the development of these natgas supplies.

## **Earth's Vast Supplies of Undeveloped Natural Gas**

Now let us look at the world's potential undeveloped natgas supplies. In 2000, the USGS estimated that 15,400 Tcf<sup>6</sup> was still in the ground, or about 150 years' natural gas supply at today's rate of consumption. This also means about 100 years' more natural gas if it successfully grows, as all indications show it will, to 150 percent of its current use, in the very near future, to displace large quantities of coal and oil.

Although this is a very important quantity for the world's natural gas consumers, it is overly conservative, for two reasons. First is the oil mind-set bias discussed previously. The second is that in the year 2000, when these estimates were made, the Middle East/Siberian size supplies of natural gas that can be developed from unconventional reservoirs in America's highly mature, declining oil provinces and several non-oil provinces such as Appalachia was not understood at all. These enormous new indicated supplies will no doubt cause the EIA and other energy-reporting institutions to begin working on new studies that, for the first time, will include the significance of the U.S. unconventional reservoirs. Natgas is just beginning to experience many of the breakthroughs necessary for unlocking the minds of estimators to the global potential for natural gas.

If my hypothesis that the world's largest natural gas supplies (not including ocean hydrates) are actually the unconventional supplies, not the conventional oil-related supplies, then a better estimate for the world's supplies still in the ground would be in the range of 30,000 to 40,000 Tcf, a supply that far exceeds the quantities of natural gas needed for it to become the principal bridge fuel to humanity's sustainable energy and climate future. And if natural gas hydrates become commercial, that estimate will double again. My bottom line is that the world has plenty of natural gas supplies to meet all its future requirements.

My 30,000 to 40,000 Tcf estimate of recoverable natural gas in the ground is partially confirmed by one of the world's largest and most

globally knowledgeable oil and gas service companies, Schlumberger. Chris Hopkins, president of Schlumberger's Data and Consulting Services, looking toward the company's future, conducted an analysis of the world's potential for unconventional natural gas. This study concluded that about 30,000 Tcf of these natgas resources<sup>17</sup> remain to be developed. Chris made his presentation during the summer of 2007 at the annual meeting of the Aspen Institute's Program on Energy, which focused on natural gas for the first time since the program began in 1978, the only other year that also focused upon natgas. With the subsequently developed abundance of shale gas in the United States, I wouldn't be surprised if Chris increases his estimate in the near future.

That 1978 Aspen Institute Energy Forum was held during America's last energy crisis and the years of false fears of natural gas shortages. It was at this 1978 conference that I presented my forecast at the time that if natgas prices were deregulated and not priced by the Federal Energy Regulatory Commission at rates that kept it in the ground, U.S. supplies equaled about 1,500 to 2,000 Tcf.<sup>18</sup> As discussed, during those years of the oil industry mind-set, Exxon, Shell's M. King Hubbert, and Mobil Oil<sup>19</sup> all publicly asserted that the United States only had between 200 and 600 Tcf left in the ground. The United States was consuming about 20 Tcf per year, so they all forecast that in about 10 to less than 30 years America's natural gas would run dry. Since that 1978 conference, about 600 Tcf of natural gas has been produced in the United States.<sup>20</sup> According to Exxon, we should have run out of natural gas by now, but after producing this 600 Tcf, most official U.S. estimates are now in my 1978 range of 1,500 to 2,000 Tcf and once again the United States has a natural gas supply surplus.

Luckily for the United States and its natgas understanding, the old boys of the oil era are being left behind by America's new independent natural gas producers. Understanding of the significance of what used to be called unconventional natural gas and the reality of natural gas abundance is growing exponentially with each new discovery.

In the next year or two, most of America's long-standing natgas estimators, including the EIA, the USGS, and Potential Gas Committee, will certainly continue to increase their estimates for U.S. natural gas supplies, just as I have since my early presentations to Congress and the Aspen Institute in the 1970s. My 1993 article "New Thinking

about Natural Gas,” included in *The Future of Energy Gases*, a volume of papers produced by the U.S. Geological Survey on natgas origin and abundance that I recommend to all as a remarkable bible for the understanding of natural gas, stated my newly increased estimate for the United States of about 3,000 Tcf, as compared to my 1978 estimates of 1,500 to 2,000 Tcf. With the recent shale and other unconventional natural gas field development, I feel even more confident that 3,000 Tcf for the United States is a reasonable estimate.

## To the Open Mind

The lead editor of that USGS volume was David Howell, a Ph.D. geologist who served in the USGS for many years. Among the many articles in the volume was also an article by the world-renowned scientist Thomas (“Tommy”) Gold, who described his theories of nonbiological origin of natural gas and oil. My article referred to Tommy’s nonbiological hypothesis because my own reality, derived from drilling deep onshore natural gas wells (experience I think most experts will agree is considerable), was that Gold’s nonbiological theory explained much better many of the conditions we had actually encountered in drilling deep, high-pressure regions of Oklahoma than what I was taught at the university.

I remain open to the possibility that, unlike oil and coal, important quantities of the world’s natural gas may not be of biological origin, just as is generally believed to be the case on so many planets in our solar system, where we know abundant natgas supplies also exist.

I tell the story of Howell’s volume because the subsequent ramifications confirmed my own deep belief about the rigidity and limits of the oil mind-set. Before it was ever published, three of the original eight members of the editorial board resigned because Dave Howell refused their demands to eliminate from the volume the articles by Tommy Gold and myself, which were perceived by them to be almost blasphemous because of our views about the possibility of natural gas’s nonbiological origin. That was only the beginning. After publication, large numbers of petroleum geologists and engineers raised such a fuss that several long-standing members of the AAPG circulated and

collected signatures on a petition that was presented to the USGS that demanded the volume be removed from all public libraries and schools.

The old oil mind-set remains strong and limiting. The days of burning books or placing Galileo under house arrest are still around within segments of the oil industry. On the one hand, I know I tell this story at the risk of annoying many peers, and I recognize that this is only an anecdotal incident and certainly doesn't relate to everyone in the broad membership. On the other hand, it is my anecdote, and it dramatically indicates the power of words, thoughts, and education to limit the minds of men and women. In this century, the understanding of natural gas is rapidly changing. Natural gas, to paraphrase Wallace Pratt, is beginning to be found in the minds of men and women.

### **A Case That Earth's Attainable Natural Gas Supplies Are Equal to or Larger than Minable Coal Supplies**

Because of the pervasive nature of natural gas in the universe, in our solar system, and on Earth, it is my hypothesis that commercially attainable natural gas resources on Earth may actually be larger than coal. The question the world's policy makers must ask is how much of the world's coal, oil, and natural gas resources are actually attainable by using in-hand technology at an economically reasonable price projected into the future. The concept of proven reserves takes into consideration technology, minability, and commerciality. By using BP's *Statistical Review of World Energy*, we see that proved coal reserves are 909 billion tons, or about 23,700 Tcf of natural gas equivalent. Proven world natural gas reserves are estimated at 6,400 Tcf.<sup>21</sup> However, the BP statistics are based on public data from the world's coal-producing nations, most of which were gathered more than 30 or 40 years ago, and recent investigations have shown that the "data quality is very unreliable."<sup>22</sup> For example, two recent European studies, "Coal: Resources and Future Production" (2007) by the Energy Watch Group (EWG)<sup>23</sup> and "The Future of Coal" (2007) prepared by the Institute for Energy (IFE) for the European Commission,<sup>24</sup> have called into question these decades-old reserve estimates. The EWG study indicates that Botswana,

Germany, and the U.K. “have downgraded their reserves by more than 90 percent” and that Poland’s coal reserves are “50 percent smaller than was the case 20 years ago.”<sup>25</sup> In 1990, even China cut its recoverable coal reserves to one sixth of its 1987 estimate.<sup>26</sup> The EWG study goes on to say that “these downgrades cannot be explained by volumes produced during this period. The best explanation is that nations now have better data from more thorough surveys.”<sup>27</sup> The IFE study states that “world proven reserves (i.e., the reserves that are economically recoverable at current economic and operating conditions) of coal are decreasing fast” and that “coal might not be so abundant, widely available, and reliable as an energy source in the future.” The IFE study concludes that “the world could run out of economically recoverable reserves of coal much earlier than widely anticipated.”<sup>28</sup>

So when we take a critical look at the world’s coal reserves, we find that they are based on sadly outdated, unreliable information generally collected in the 1970s, or possibly even decades earlier, and they do not reflect current mining safety or environmental regulations nor current economic conditions in many nations. These writedowns are only now beginning to be reported in national statistics and will no doubt continue in the future as more studies are initiated. As retired U.S. Geological Survey coal expert Harold Gluskoter said, “40 percent of the world’s coal disappeared in three years”<sup>29</sup> of reporting.

It should trouble policy makers that most coal reserves have been established using methods and data from the 1970s or before, and that recent studies in Europe<sup>30</sup> and the United States<sup>31</sup> are significantly downsizing the reserve estimates of commercially minable coal. Although the BP statistics indicate 23,700 Tcf equivalent of proven coal reserves, over three times larger than the 6,400 Tcf of proven natural gas, a credible case can be made that proven natural gas is probably closer to twice what is reported, or over 12,000 Tcf equivalent (see “More Proven Natural Gas Than Is Estimated” earlier in chapter). When independent and standardized modern estimates of coal are completed, proven coal reserves could be no more than half of what is currently reported, or also about 12,000 Tcf.

When we recognize that the recent shale and other unconventional sources of natural gas supplies are not included in today’s world estimates, and that estimated coal reserves are based on highly

unreliable, outdated information, there is a reasonable probability that the world's proven natural gas reserves are about equal to proven minable coal reserves.

It is clear that there is an urgent need to update coal reserve estimates, as well as natural gas estimates that include today's unconventional reserves, so that policy makers can base their long-term decisions on reliable, modern data. If it hasn't already, the IEA should immediately commence such a study.

### **America's Attainable Natural Gas Supplies May Equal or Exceed Movable Coal Supplies**

I realize that what I am about to say will create great controversy, but I also believe it is my responsibility—so here goes.

We have all heard the coal industry's oft-repeated boast that the United States is the "Saudi Arabia of coal." The idea that the United States has 250 years of coal supplies has been repeated so often that it has become almost a part of our culture and, unfortunately, gives policy makers what I believe to be excessive comfort. Until I recently began to dig deeper, I, too, was part of a public assuming nearly unlimited coal supplies. However, a 2007 report, "Coal: Research and Development to Support National Energy Policy," by the National Research Council of the National Academies,<sup>32</sup> originated by U.S. Senators Robert C. Byrd and Arlen Specter, reveals that this assertion is based on unreliable and outdated information that was collected in the early 1970s and before today's increasingly stringent mining safety and environmental regulations, which have rendered large amounts of what was formerly thought to be reserves either noncommercial or environmentally out-of-bounds.<sup>33</sup> The Council states, "It is *not possible* [my emphasis] to confirm the often-quoted assertion that there is a sufficient supply of coal for the next 250 years."<sup>34</sup> That 250 years has been based on approximately 267 billion tons of estimated recoverable reserves.

Because of the old age and poor quality of this essential data that the Council called "outdated, fragmentary or inaccurate,"<sup>35</sup> we must not base future policy upon these estimates until they are further confirmed. Indeed, in its attempt to spot-check these outdated estimates, the

Council reviewed “limited areas”<sup>36</sup> and warned that “only a *small fraction* [my emphasis] of previously estimated reserves are economically recoverable.”<sup>37</sup> Therefore, it is likely that the ongoing USGS systematic inventory of the U.S. coal reserve base will significantly reduce available supplies. Indeed, in its first recent assessment of America’s largest coal field around Gillette, Wyoming, which currently produces 38 percent of U.S. demand, the USGS reduced its estimate of the coal reserves by about 30 percent.<sup>38</sup>

In order to carefully assess the future of coal, we must understand the difference between coal resources and reserves. Resources are the quantities of coal that the mining industry think might be in the ground and are potentially minable. Because there is a lot of coal in the ground, the United States and the world has huge resources, but these quantities have no practical bearing on how much coal can be commercially mined. Rather, these quantities are similar to the enormous amounts of natural gas hydrates around the world that we know are there but are not yet technologically or economically attainable.

To understand the future of coal, we must carefully inspect the coal *reserves* defined as “the part of the coal resource that can be mined economically, at the present time, given existing environmental, legal, and technological constraints.”<sup>39</sup> By applying these constraints and taking into consideration the Council’s warning that only a “small fraction” of the previously indicated reserves may be commercial, the future of coal looks much less reliable than what is widely assumed.

In answering the question of whether the United States has reserves sufficient to meet the EIA’s production estimates until 2030, the National Research Council says “definitely yes,”<sup>40</sup> citing about “19 billion tons of recoverable reserves at active mines,”<sup>41</sup> or about an 18-year supply. The Council goes on to say that this is augmented by another “60 billion tons of reserves held by private companies.”<sup>42</sup> However, to assess these reserves in the near- and medium-term future, we must remember that to the extent the additional 60 billion tons are not located within existing mines, it will likely take from “7 to 15 years”<sup>43</sup> to plan, permit, and open a new large mine. Like all large infrastructure projects, costs are skyrocketing and times to completion are increasing dramatically.

The 19 billion tons, or 496 Tcf natural gas equivalent, of coal reserves that can be produced from active coal mines compares to U.S.

proven natural gas reserves of 238 Tcf.<sup>44</sup> However, two facts keep this from being a truly “apples to apples” comparison. First, it is my analysis that the SEC reporting regulations are more stringent for natural gas than coal. The SEC requires the annual natural gas engineer’s reports to have at least 90 percent probability, which generally results in overly conservative calculations.<sup>45</sup> However, as a comparison, the “old and out-of-date”<sup>46</sup> coal data that continue to be used have been shown to be too large as a result of the spot checks reported on by the National Research Council and the recent 30 percent writedown by the USGS of the coal reserves around Gillette, Wyoming. Because the Gillette mines have been so important for America, producing about 38 percent of America’s coal, my experience leads me to believe that the former estimates that predated the USGS writedown should have been the country’s most detailed, up to date, and accurate. This calls into question the rest of the nation’s remaining reserves.

The second difference arises from my 50 years of experience that estimates of proven natural gas reserves *in the early years* of production are generally less than 50 percent of ultimate production, as explained earlier in this chapter. Considering that nearly 50 percent of U.S. natural gas production is from wells that are less than five years old, a credible case can be made that a more realistic estimate of America’s ultimate production from proven natural gas reserves would be in the range of 400 Tcf. If the USGS’s comprehensive, ongoing study of coal reserves from active mines results in an across-the-board 30 percent writedown, proven coal reserves will be the equivalent of about 350 Tcf (19 billion tons of “recoverable reserves at active mines,”<sup>47</sup> or 496 Tcf equivalent times 70 percent, which equals about 350 Tcf), as compared to U.S. proven natural gas reserves that I estimate to be near 400 Tcf. U.S. proven natural gas reserves may well be larger than its proven minable coal reserves.

The coal industry argues that there are an additional 60 billion tons, or 1,566 Tcf equivalent of reserves, “held by private companies”<sup>48</sup> that must be included. I accept the position, but in order to have an apples-to-apples comparison, I believe that much of this 60 billion tons (1,566 Tcf) of coal not attached to “active mines” should be compared to the natgas supplies that are not from producing natgas wells or their immediate offsets and, therefore, are generally comparable to an

important portion of the estimates of undeveloped natgas supplies as estimated by the Potential Gas Committee, USGS, EIA, and Navigant. These supplies, which are beyond the limited area of producing natgas fields, are estimated to be from about 1,300 to 2,000 Tcf. Based on the premise that coal reserves that are not assigned to active mines, sometimes called “unassigned,” are not further reduced by the forthcoming USGS work, then their 60 billion tons, 1,566 Tcf equivalent, may be generally compared to the recent natgas estimates of about from about 1,500 Tcf to over 2,200 Tcf<sup>49</sup> by independent estimators and about 2,800 Tcf by my own work. The difficulty here is attempting to achieve a realistic comparison. I recommend that the USGS try to do this as soon as its new coal assessment is completed.

Once again, when we look beyond the coal industry’s rhetoric of abundance, there is a good case to be made that for the mid- and long-term future, natural gas and coal may be about equal. Although they may be about equal now, there is no question that the trend for coal reserves estimates in the United States and around the world is down and that natural gas reserve estimates are being increased rapidly.

When the Council looked further into coal’s future, the situation became much less clear. The Council states that “there is *probably* [my emphasis] sufficient coal to meet the nation’s need for more than 100 years at current rates of consumption.”<sup>50</sup> In the big picture, this may be the most realistic comparison between coal and natural gas supplies. If we do the math, this forecast approximately equates the Council’s coal projections of a 100-year supply with the 2008 Navigant, Inc. estimate that also indicates a 100-year supply of natural gas. So 100 years of coal consumption is about 110 billion tons, or about 2,870 Tcf equivalent of natural gas. This 2,870 Tcf coal equivalent compares to Navigant’s 2,247 Tcf and my personal estimate of 3,000 Tcf.<sup>51</sup>

Once again, based on the most recent information and evidence, there is an equal or slightly larger quantity of attainable natural gas than there is coal.

The point of this exercise is to initiate an important debate about America’s energy future by calling attention to the reality of natural gas abundance in the United States, and by calling into question the widely held assumption, thought to be a fact by many policy makers, that coal

is so abundant that we don't have to worry about basing long-term policy on this presumption.

The reality is that enormous quantities of coal have been mined in the United States, especially over the past 100 years, and most of the best and easiest coal is gone. Many recent safety and environmental regulations have eliminated lots of coal from the possibility of ever being mined. For the last 30 years, national policy has been based on the understanding that we don't have to worry about coal supplies because America is the "Saudi Arabia of coal" and, therefore, it has almost been presumed that it is our *obligation* to figure out how to use coal for America's future. As a result, large quantities of the U.S. taxpayer's money has gone for development programs for the use of coal (\$538 million in 2005<sup>52</sup>) and tragically little has been expended to understand natural gas and its technology and future.

Based on the information I have just recited, it seems logical to me that our research for carbon capture and sequestration (CCS) should also be undertaken in conjunction with natural gas generation that produces 50 percent of the CO<sub>2</sub> as the same-size coal-generation facility. And because natural gas contains little of coal's other non-CO<sub>2</sub> emissions and virtually none of its toxic wastes, a natural gas power plant with CCS will be just about as green as wind and solar.

## **Natgas Ascends; Coal Declines**

Looking to the future, we recognize that because most of the nation's highest-quality coal has already been mined, our future coal reserves will be of lower quality. Indeed, in terms of energy content, one analyst says U.S. coal production peaked in 1998<sup>53</sup> and may continue down. This reduction in energy content has been more than compensated for by Wyoming's lower-grade subbituminous coal; so to maintain the energy produced by coal today we will need to continue to increase the volumes of coal used. Larger volumes of lower-quality coal will increase the CO<sub>2</sub> that will be produced from coal electric generation, resulting in the need for ever-increasing carbon capture and still larger quantities of CO<sub>2</sub> sequestration.

To drive this point home, I will quote the National Research Council:

Almost certainly, coals mined in the future will be lower quality because current mining practices result in higher-quality coal being mined first, leaving behind lower-quality material (e.g., with higher ash yield, higher sulfur, and/or higher concentrations of potentially harmful elements). The consequences of relying on poorer-quality coal for the future include (1) higher mining costs (e.g., the need for increased tonnage to generate an equivalent amount of energy, greater abrasion of mining equipment); (2) transportation challenges (e.g., the need to transport increased tonnage for an equivalent amount of energy); (3) beneficiation challenges (e.g., the need to reduce ash yield to acceptable levels, the creation of more waste); (4) pollution control challenges (e.g., capturing higher concentrations of particulates, sulfur, and trace elements; dealing with increased waste disposal); and (5) environmental and health challenges.<sup>54</sup>

None of this is true for natural gas. Indeed, because of the ongoing increases in turbine efficiency, we can confidently project increased efficiencies for natgas-generated electricity that will lower CO<sub>2</sub> emissions per megawatt produced.

In conclusion, to have a bit of fun during the deadly serious debate over America's future energy and climate policy, let me say that when I presented my natural gas estimates at a prestigious energy and climate roundtable held during the Democratic National Convention, Fred Palmer, senior vice president of Peabody Energy and a member of the executive committee of the National Coal Council, called my natural gas estimates "wildly optimistic." In view of the most recent assessment of coal reserves that I have laid out here, I believe Fred's "wildly optimistic" remark might better be applied to the coal industry's boast that America is the "Saudi Arabia of coal." What is obvious is that it is extremely urgent that studies be conducted to validate both coal and natural gas reserve and resource estimates in time to formulate and pass long-term energy policies for America's energy future.

## **A Call for More Natural Gas Education**

To sum up, oil is either at or fast approaching its peak ability to meet future demand, and there are indications that coal may also be on the way to its own limits. Yet, development of the world's vastly abundant natgas supplies has only recently begun to accelerate. This acceleration is principally due to the overdue recognition of the abundance of natural gas and the fact that in many countries, the price of natgas, for the first time in the history of its use, had recently began to rise to levels sufficient to bring forth new private-sector capital budgets focused on natural gas exploration and production. As a result, the days of the mistaken perception of peak natural gas are rapidly fading away and will continue to be replaced by a new natgas mind-set of abundance. We will see evidence of this change of mind-set as forthcoming publications are presented by the various institutes charged with presenting natgas supply estimates. Most important, after nine years of generally flat production, the recent breakout of growth in the United States is a positive indicator of a new natural gas paradigm.

From now on, natural gas will continue to come to the forefront and break through the many historical barriers of its association with oil, becoming known as the number one clean alternative fuel to help solve the world's energy and climate problems in the near and medium term. Natural gas is truly the bridge fuel to civilization's sustainable future.

I believe that in order for civilization to meet its natural need for growth, continually increasing quantities of energy will be required and that natural gas abundance will provide the bridge to meet that growth, along with the rest of the sustainable, virtually unlimited fuels of the Age of Energy Gases.

Much of the evidence for natural gas abundance I have expressed is based on a large accumulation of personal experiences within the natural gas exploration and production industry, as well as anecdotal evidence, yet, as sound as I believe the experiential evidence to be, I recognize that it is not the equivalent of hard academic and scientific evidence.

Vastly more academic studies and field reality checks are needed to produce more scientific evidence. So I recommend that the world's

governments immediately allocate more funds for natgas research and development, which has always been a low priority. In 2000, my alma mater, the University of Oklahoma, took a stride forward and developed its first program for a master's degree in natural gas engineering. I encourage universities around the world to originate in-depth programs focused on natural gas, and I encourage all students interested in science, energy, and changing the world for the better to enroll.

As a lifelong worker in the natural gas field, one whose estimates have proven more accurate than most of the world's natural gas forecasters over the last 30 years, I respectfully submit that the entire field of natgas science and studies stands about where we were in the 1980s with climate science. Then, evidence clearly pointed toward the belief that human CO<sub>2</sub> emissions were driving global temperatures upward, but we needed hard scientific evidence. It is equally important that we advance natural gas studies—just as we did climate studies that are now more grounded in scientific evidence—so natural gas resources can gain the widespread scientific credibility necessary to serve as the basis of policy decisions for the resolution of civilization's energy problems.

## **A Plea to the World's Journalists**

This chapter closes with a plea to the world's journalists. As you know better than anyone, words are powerful and leave lasting impressions. In this critical period that demands enlightened action on energy and climate policy, there is great confusion in contemporary energy vernacular, as sketched in this presentation on natural gas abundance. One of the most dangerous terms used is *fossil fuels* as a catchall for coal and “oil and gas.”

This presents a real problem. “Fossil fuels” lump natural gas—one of our twenty-first-century energy solutions—with the two largest energy problems, coal and oil. By repeatedly reading and hearing those words, the public and policy makers are bombarded by a highly negative connotation that rings true for coal and oil, but that could not be further from the truth for natural gas.

First, there is a reasonable probability that significant quantities of natural gas may not be biological but rather an outgassing from the

mantle and, therefore, not “fossil” at all. Certainly all the natural gas from garbage and refuse dumps is not fossil in origin. If the Earth’s deep hot biosphere turns out to contain more microbes that produce natgas than we know, then these quantities of natgas should actually be considered *renewable*.

There is little question that coal and oil are fossil, nonrenewable, and represent the majority of the world’s energy problem. But, there remains an open question about how much natural gas is of fossil origin and how much may not be. No matter the origin of natural gas, there is no question that it is globally abundant and will become an increasingly important part of the world’s energy solution. We must not mix *problems* with *solutions*.

Journalists of the world: Please stop using the term *fossil fuels*. Rather, call each fuel by its name: coal, oil, or natural gas. By doing so you will serve your audience well and help the world sort through its civilization-threatening energy and climate problems. Coal and oil must rapidly become our energy past, but natural gas is truly a critical part of our energy future. This book’s Glossary is recommended reading for journalists, policy makers, and the public.